



**JLOTS R&D Symposium
29-31 Jan 2002**

ADVANCED SHIPBOARD CRANE MOTION CONTROL SYSTEM ATD

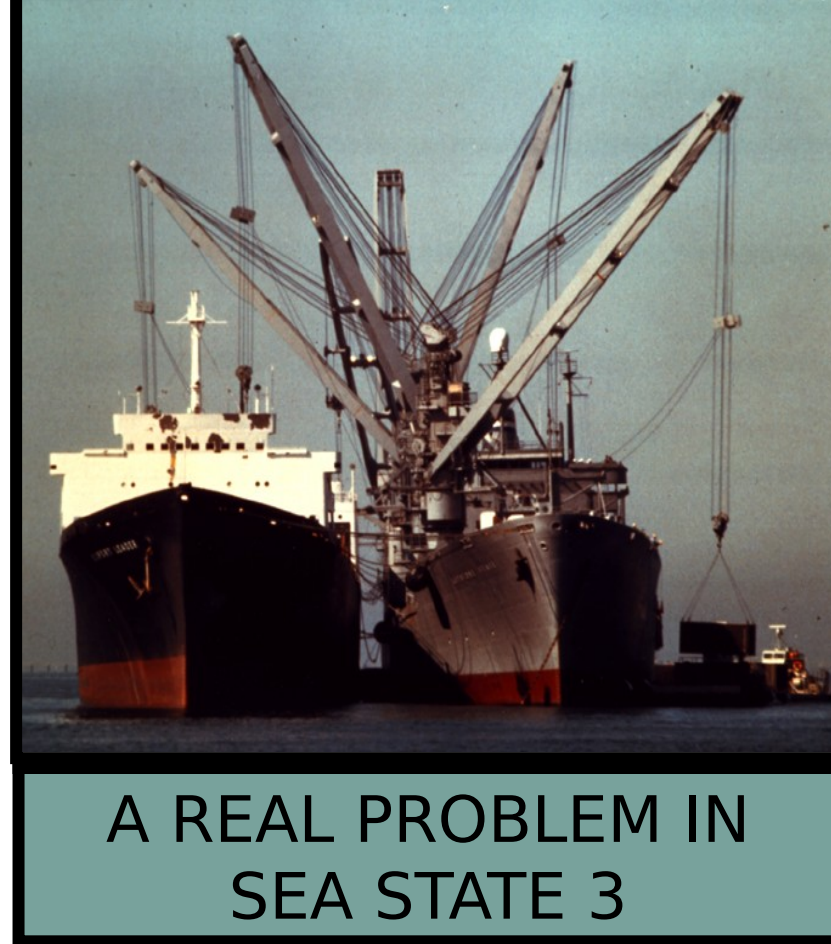


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Technical Manager: ONR 362, Dr. Abraham
Program Manager: PEO EXW; PMS 325A, Mr. Fink
Program Execution Manager: NSWCCD 282, Mr. Rausch

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Topics

- **Overview**
- **Requirement Need**
- **Technical Approach**
- **Algorithm Progress**
- **Simulator Progress**
- **Stimulator Progress**
- **Transition**
- **Conclusions**



Problem - Pendulation

Load pendulation is caused by:

- crane operator
- ship motion
- system dynamics

Pendulation slows all crane operations in any sea state and prevents any safe crane operations from high sea state 2 through sea state 3.

This ATD solves these problems



ATD OBJECTIVES:

- Demonstrate shipboard crane pendulation motion control.
- Enable crane ship throughput of a minimum of 300 containers per day in sea state three.

Requirement - Joint Logistics Over The Shore

JLOTS operations through
sea state 3 on Integrated
Priority List for all
warfighting CINCS

Littoral Combat
and Power
Projection FNC
Distribution

Cargo
Ships

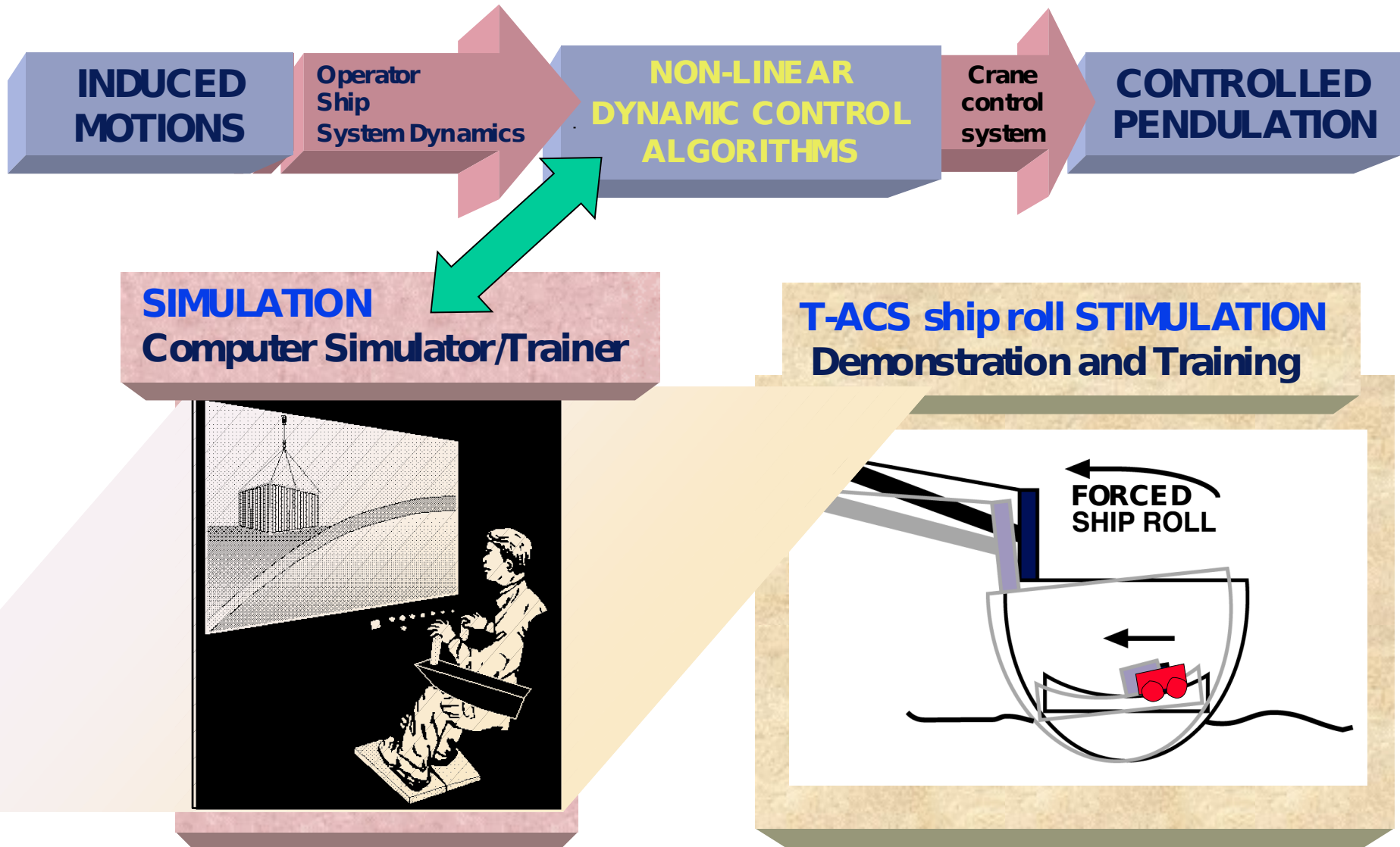
Ship Transfer/
Cranes/Ram

Lighterage
(ACTD)

Shore
Systems

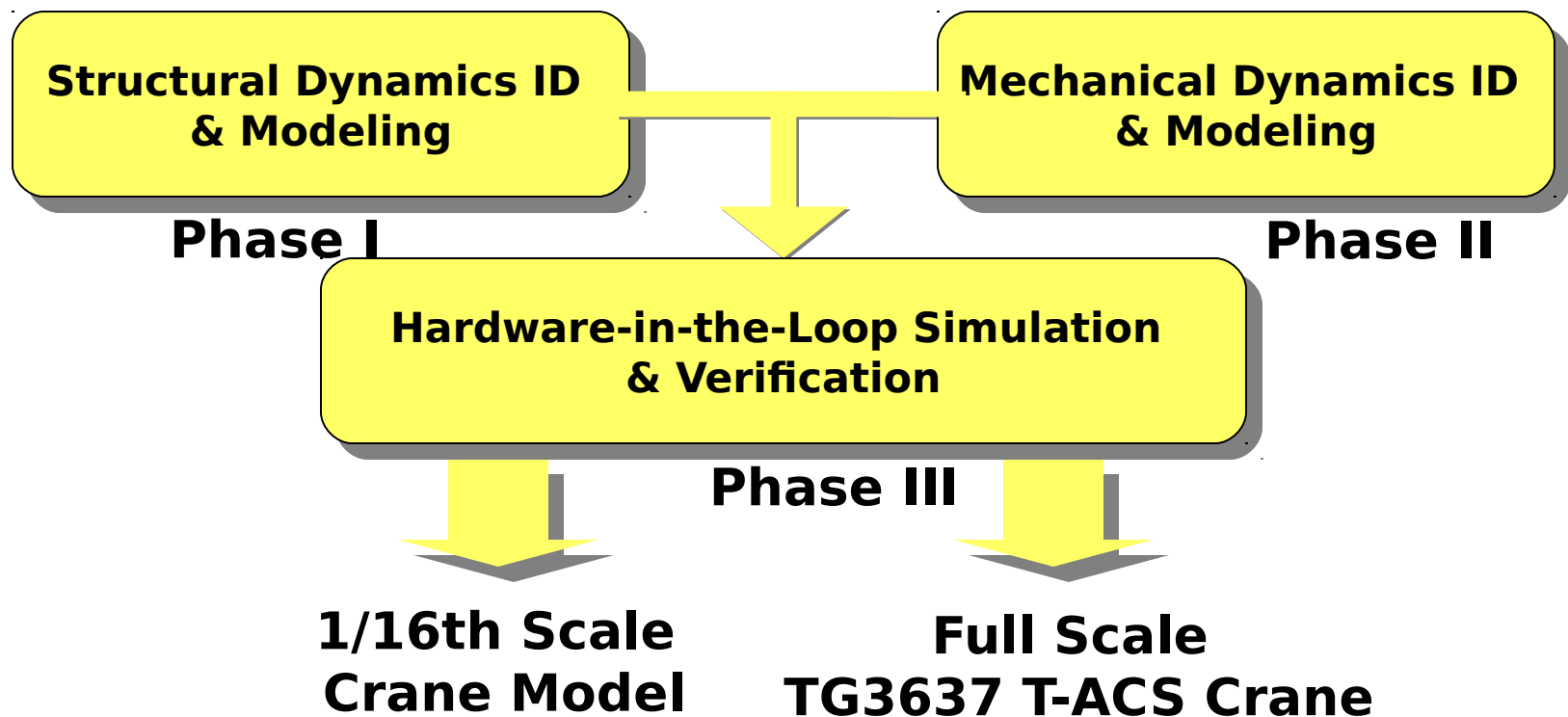
Beach
Clearance

TECHNICAL APPROACH



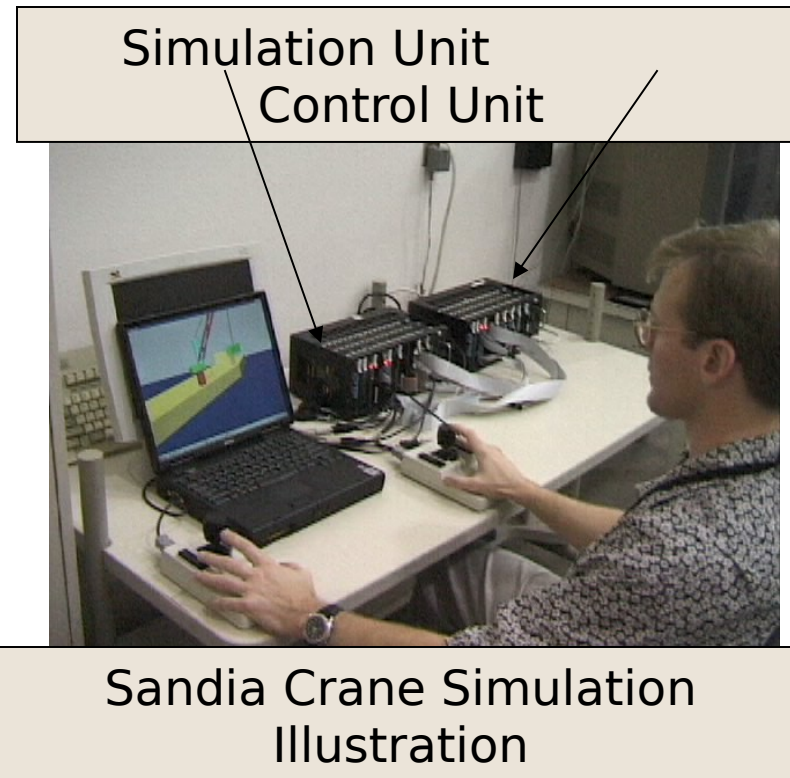
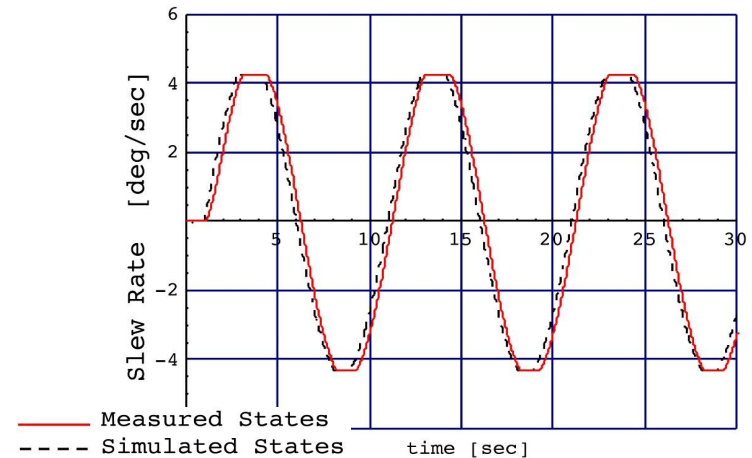
Swing Free Controller (SFC) Algorithm Development/Implementation Strategy

Maximize the use of the Sandia 1/16th scale crane model as testbed for full-scale methodology



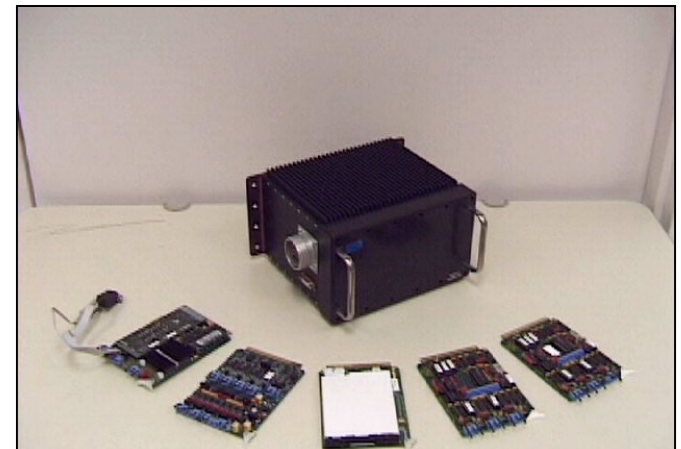
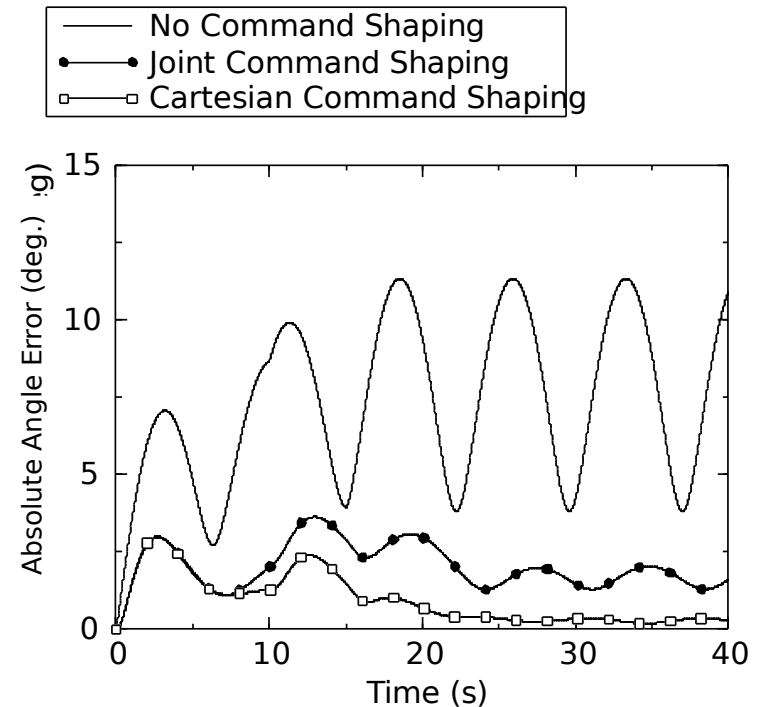
1/16th Scale Crane and TG3637 Crane Characterization

- **Structural Dynamics ID**
 - Identified basic structural flexibility modes
- **Machinery Dynamics ID**
 - Developed first generation drive system model
- **Hardware in the Loop Simulation & Verification**
 - Modal test and drive system ID results incorporated into simulation
 - Final Verification of TG3637 crane will occur when the swing sensors are installed in FY02



Controller Improvements

- **Controller mod to perform input shaping in Cartesian space instead of joint space.**
- **Control code ported over to a stand-alone controller box.**
- **Controller communication specifications established**
- **Crane drive system bandwidth and rate limitation issues under investigation**

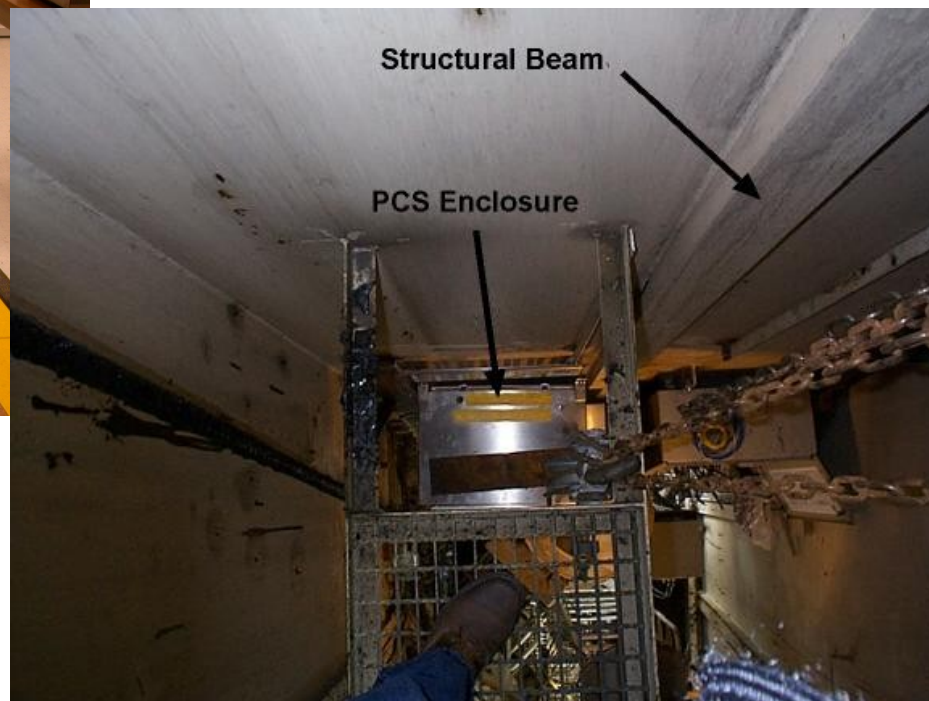


Shipboard SFC Unit (Sealed)

FY02 Milestones

- MGC Contract
 - Drive Upgrade
 - Velocity Servo
 - Structural Analysis
- Install: controller,sensors,display
- Swing-Free Controller (SFC) Upgrades
 - Fault tolerance
 - Lighter/deck tracking
 - Under-actuated
 - Ops
- System Testing

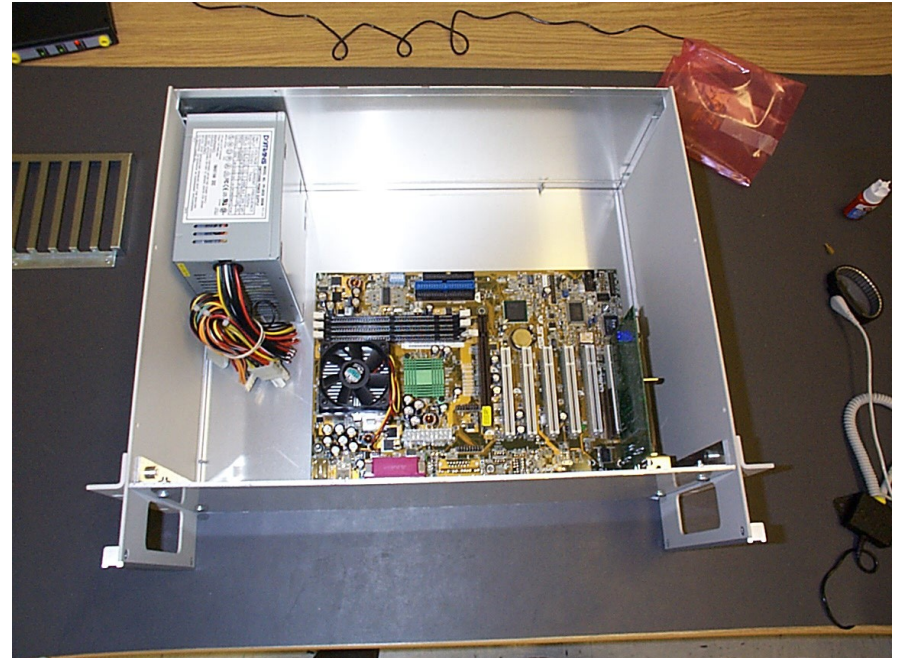
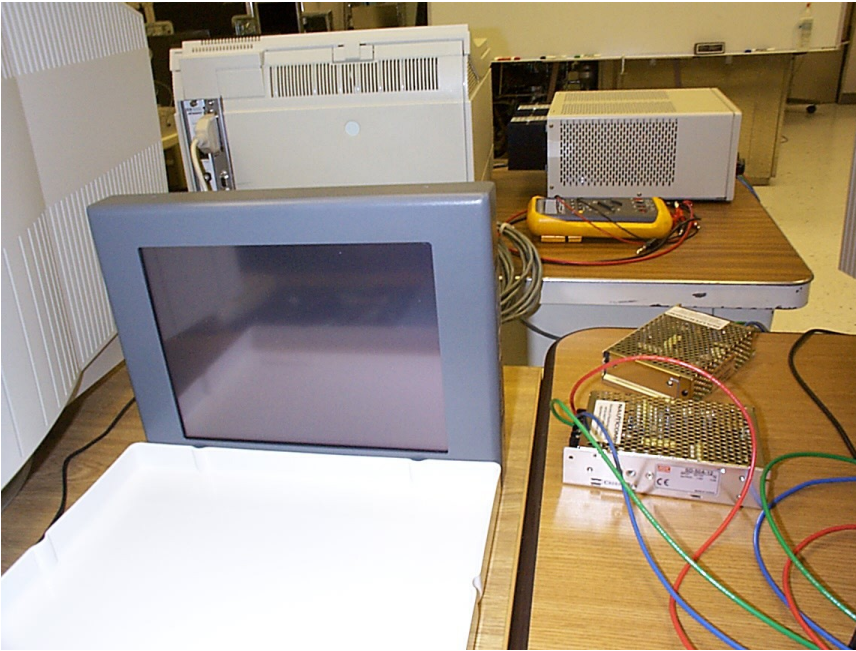
SFC Enclosure



SFC Systems



Operator Display



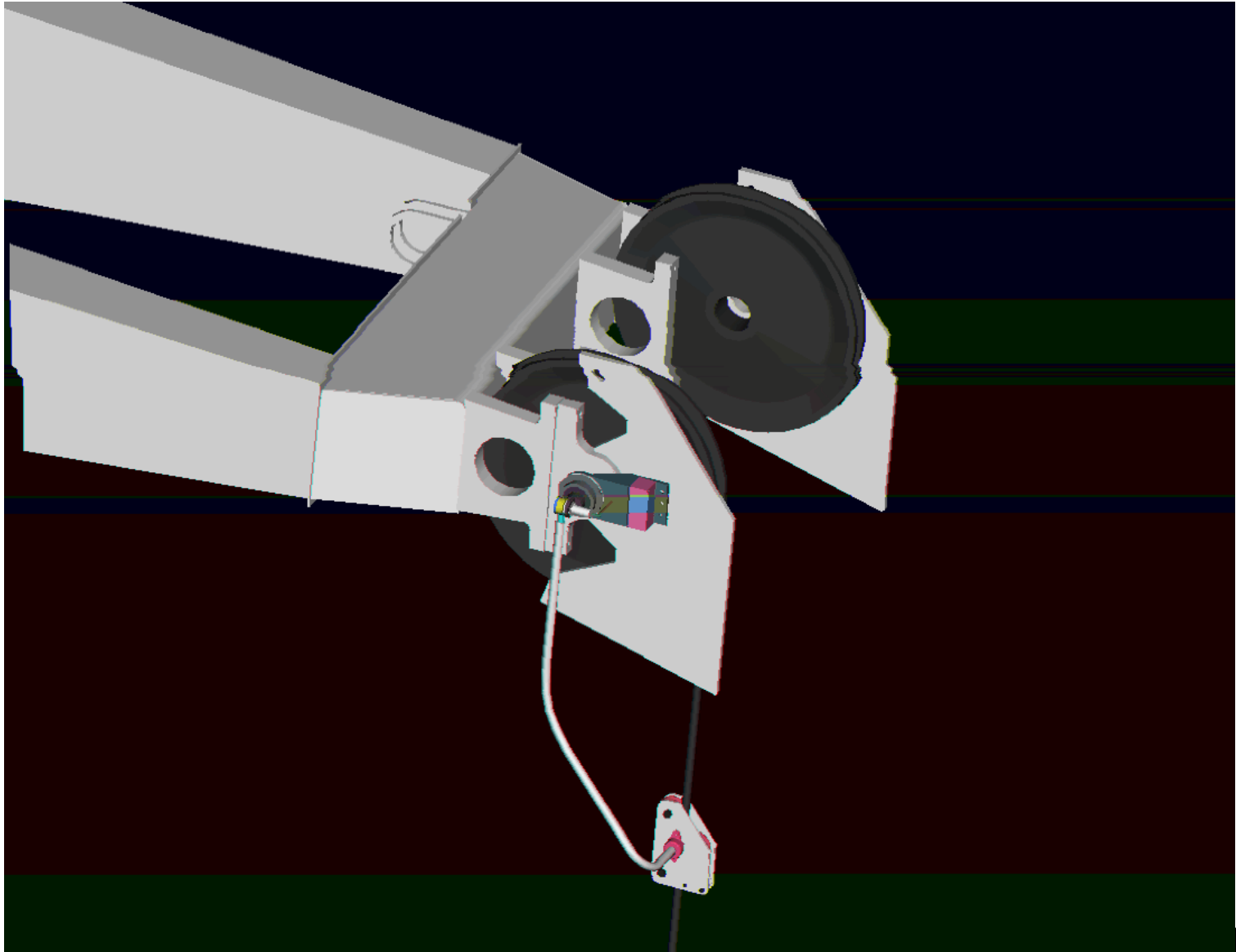
Ship Motion Sensor



Ship Motion Sensor Install



Swing Sensor



Crane Simulator / Trainer



Crane Simulator Design and Fabrication Contract Award

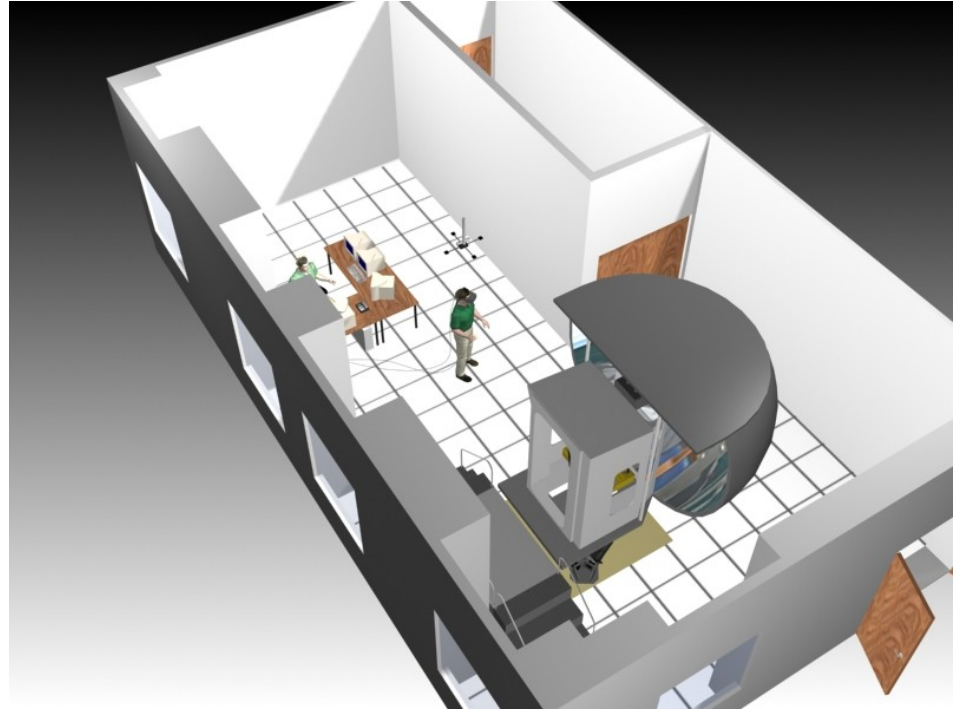
- **System Specification Complete**
- **System Fabrication Complete**

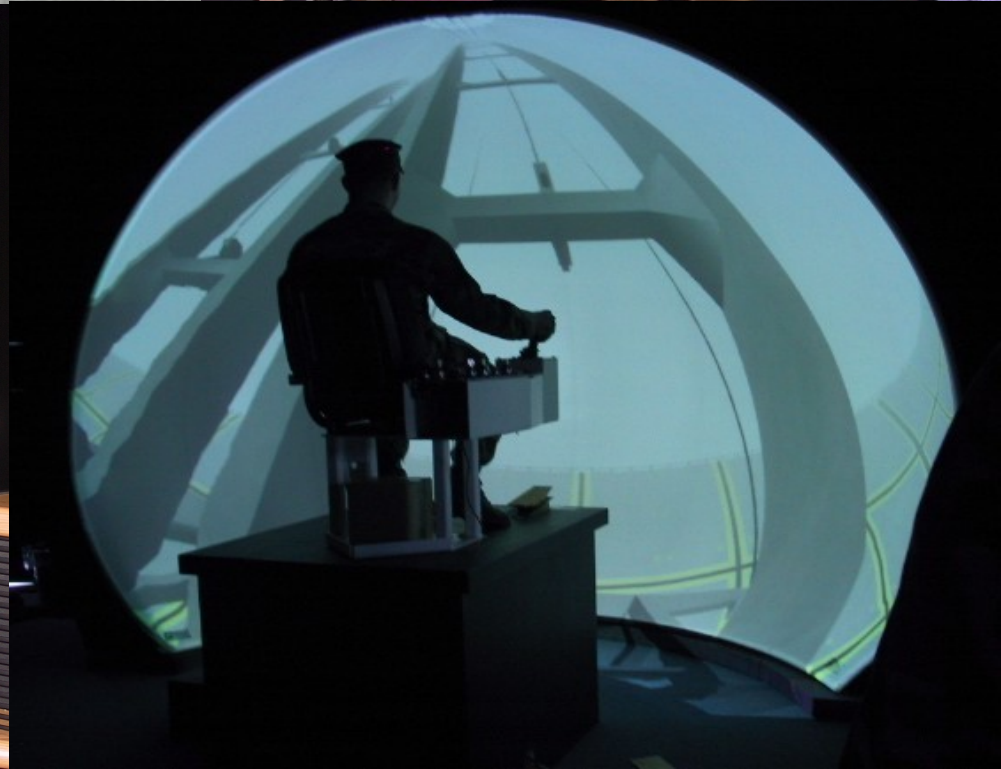
FY01 Milestones

- Oct 2000 – Open loop testing of 1/16th scale model (Crane model validated)
- Feb 2001 – Closed loop testing of 1/16th scale model (validates 1/16th scale swing free controller)
- Crane simulator design specification completed
- Initial trainer version fabrication completed

FY02 Milestones

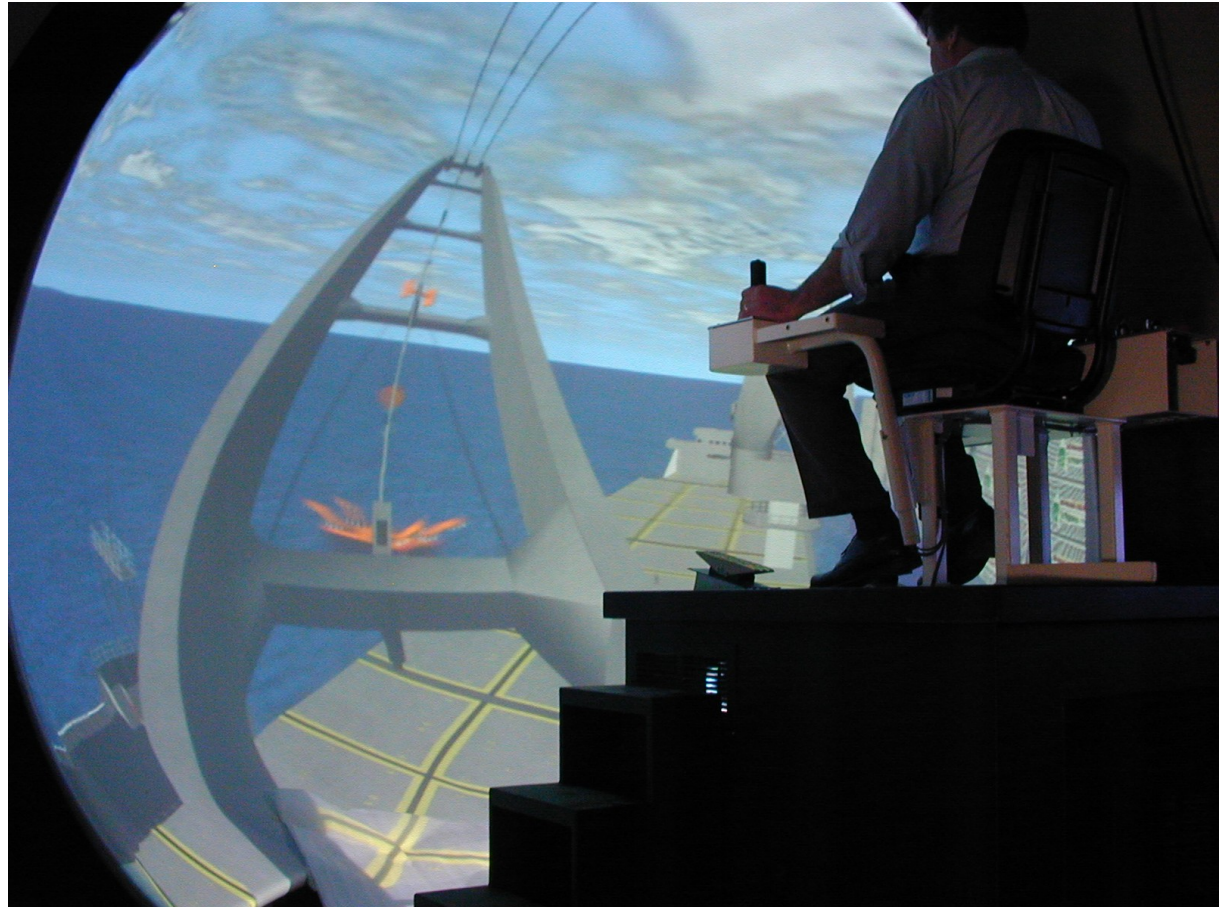
- Dec 2001 - initial trainer installation at Cheatham Annex
- Planned trainer upgrades:
 - #1: Feb 2002 - contact dynamics, crane mockup
 - #2: Apr 2002 - signal man station, video recording, intercom system
 - #3: TBD 2002 - high fidelity coupled vessel hydrodynamics
- Simulator and other trainer upgrades
 - MacGregor cc2000 box integration, Sandia SFC box integration, crane cab auxiliary display
- Support for May and July 2002 pierside demonstrations





Crane Simulator Multi Use

- Engineering testbed for swing-free controller (SFC) and other computations
- Confidence builder prior to SFC shipboard installation
- NAVCHAPGRU training
- Army crane oper. training





SHIP ROLL STIMULATOR SYSTEM

**Max Weber has just retired
Walt Beverly has replaced
Max**

Code A42, CSS

Task Overview



Induce accurate, repeatable, and sustainable T-ACS ship roll, up to ± 3 degrees, dockside and at anchor. Provide a cost effective test platform to validate future R&D crane improvements. Side benefit: realistic crane operator test facility for typical JLOTS “at anchor” crane operations.

Review of SRSS Requirements

- Develop a modular system for T-ACS 5 to produce up to ± 3 degrees ship roll
- Controllable within period variation due to ship loading in the range 6-26 Seconds
- Conform to available ship space
- Removable (or disabled) within a two day time frame
- ABS and Coast Guard approved system
- Safe to operate
- Operational at pier and at anchor

SRSS STATUS REVIEW

Implementation Team:

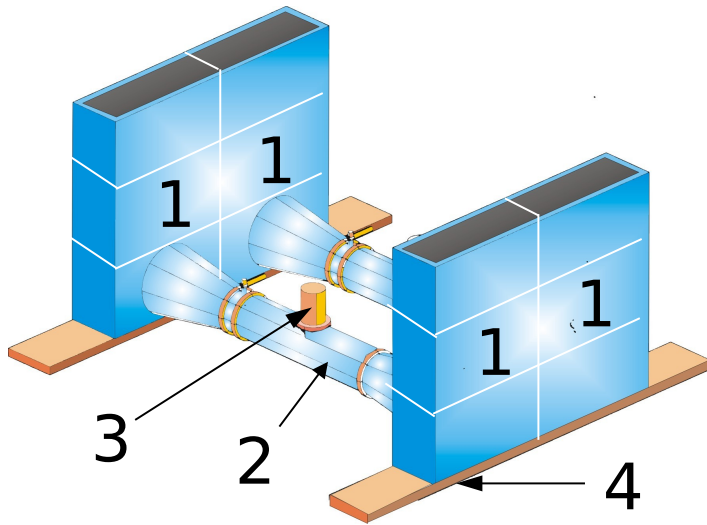
- **NSWCCD - ATD Manager (A. Rausch)**
- **NSWCDD (CSS) - Project Engineer (W. Beverly))
Sr. Engineer (S. Naud)**
- **NAVSEA PMS325R3 - Advisor/Consultant (M. Fink)**
- **Craft Engineering - Design/Fabricate/Install (D. Bird, L. Lucero)**
- **MARAD Hq - Ship Interface and Usage Control (A. Margan)**
- **T-ACS 5 Crew - Ship/System Interface (B. Fitzgerald, S. Stilianos)**

FY02 Milestones

Status

•Approval of design and installation by ABS & Coast Guard	Completed, 1 st Q
•Pier-side performance tests	Completed, 1 st Q
•Pier-side demonstration	Completed, 1 st Q
•Initial operator training	Completed, 1 st Q
•Procure tools and spare parts	2 nd Q
•Operation & Maintenance Manual (Final)	2 th Q
•Stimulation Mechanism Demonstration Report	2 nd Q
•Investigate automatic SRSS control (CSS)	2 nd Q
•System training as needed	3 rd Q
•At anchor demonstration: Joint NSWCCD/NSWCDD	3 rd /4 th Q
•Automatic control design/implementation	4 th Q
•Support Sea State 3 crane tests and demonstration	4 th Q

SRSS Main Components



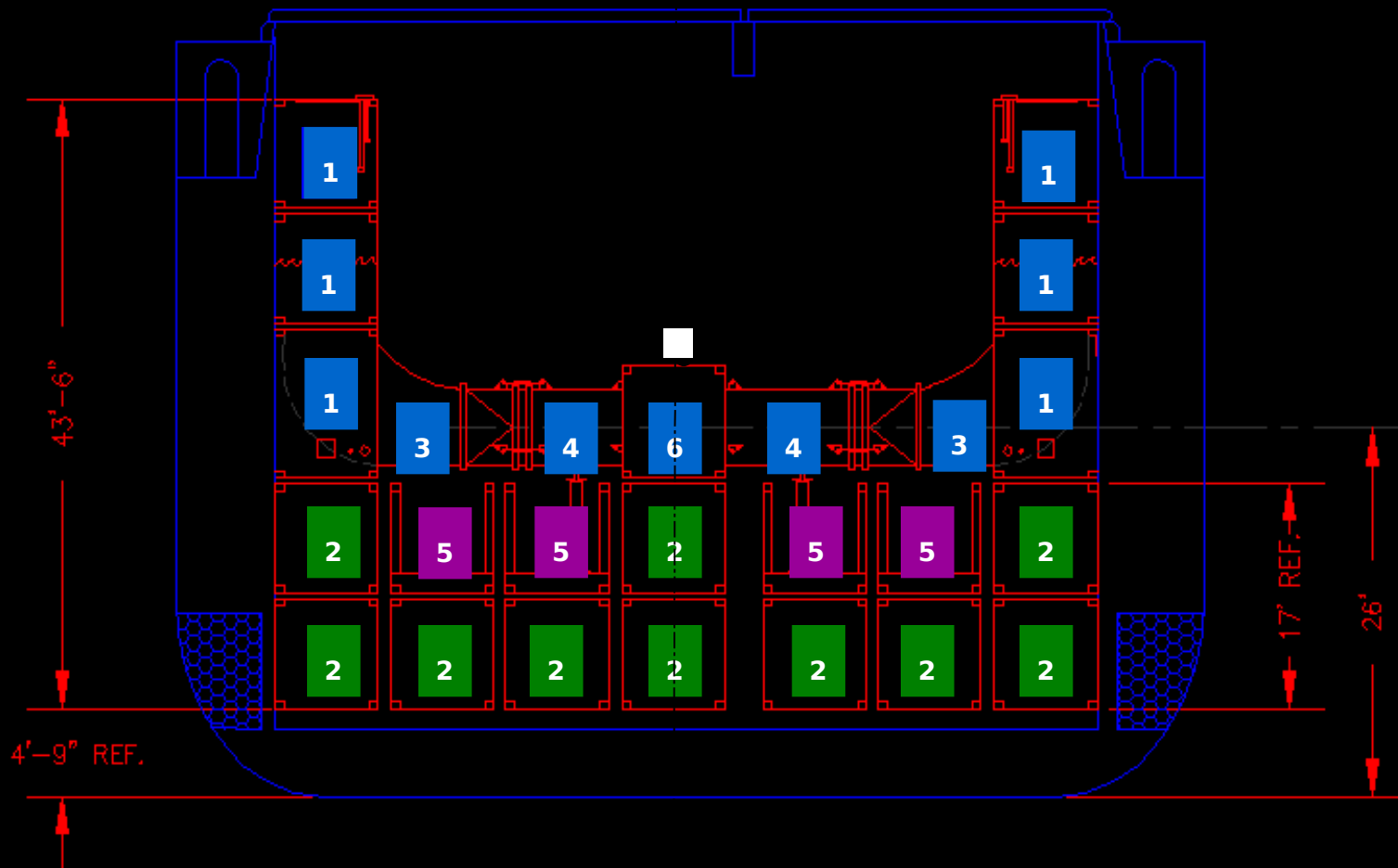
FLUME TANK SYSTEM

- 1. Water Tanks
- 2. Transfer Tubes
- 3. Hydraulic Bow Thruster Units
- 4. Base Mounting Structure

**Modular
Design**

5 Operating Specifications; Single Unit

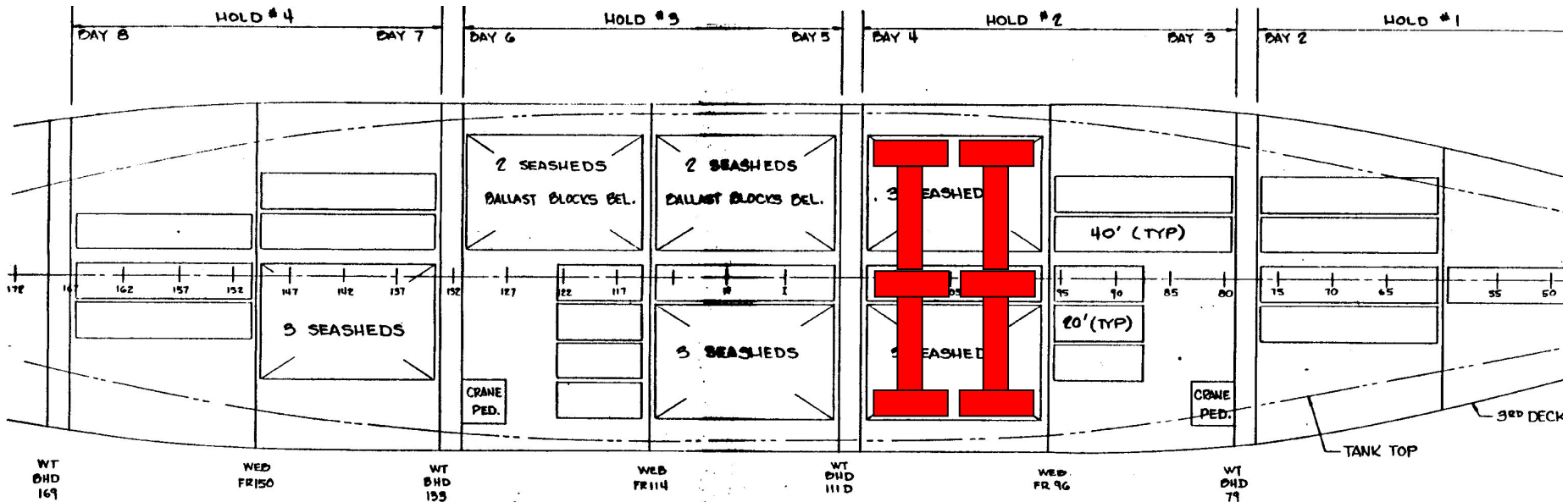
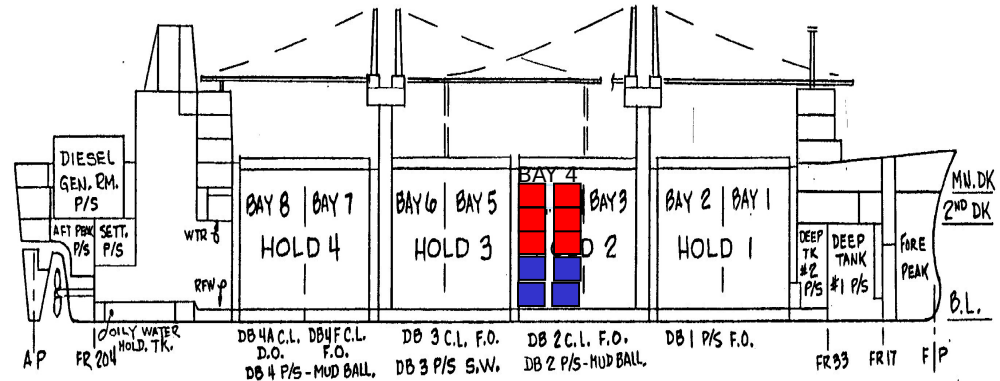
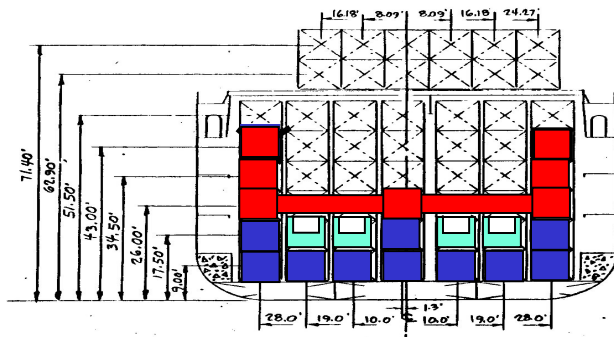
Horizontal cross sectional area of stack tanks	145 square feet
Stack Height (93" + 105" + 105")	25' - 3"
Minimum water height due to pump cavitation limit	8' - 0"
Maximum water height to provide 4' safety margin	21' - 0"
Average water height	13' - 0" (+/- 3 foot active motion)
Maximum volume transferred	+/- 440 cubic feet
Maximum weight transferred	+/- 27,390 pounds
Maximum flow rate	120,000 gpm
Maximum water velocity	12 feet per second
Operating water capacity	32,000 gallons
Operating water weight (includes water in cross pipe)	265,000 pounds
Maximum stack weight per 20' container cell	226,000 pounds
Allowable weight of 6 high, 20 LT, 20' containers	268,800 pounds
Power supply	300 amp, 480 volt, 3 phase, 60
Maximum Operating Horsepower	200 Hp hertz



(Holds AC Motor, Hydraulic Pump, Bow Thruster, & Misc. Parts)

SRSS INSTALLATION

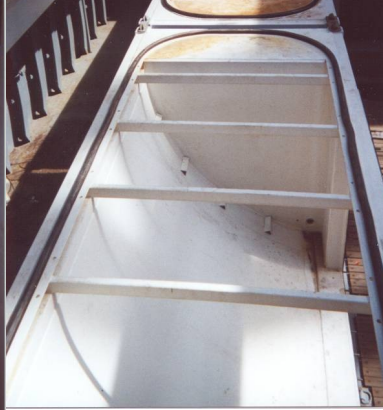
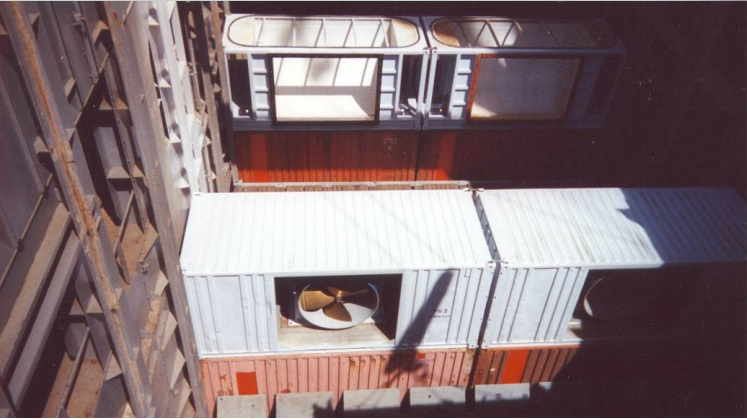
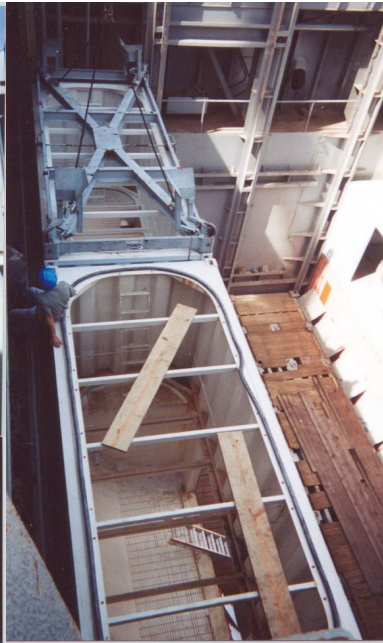
SRSS Location: Hold 2, Cell Group 4
SS FLICKERTAIL STATE



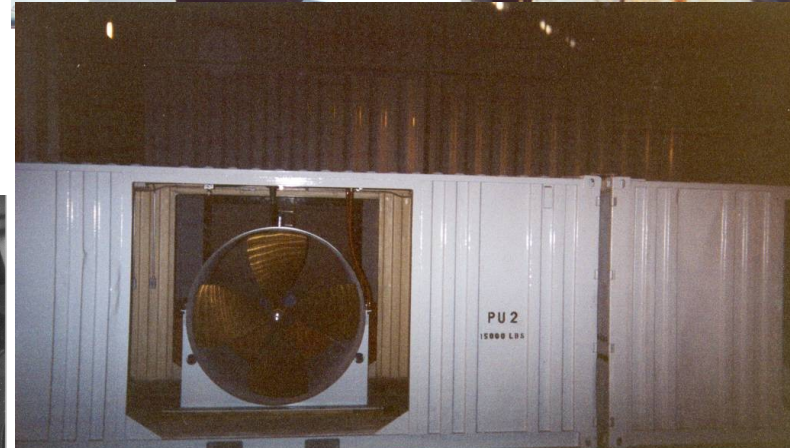
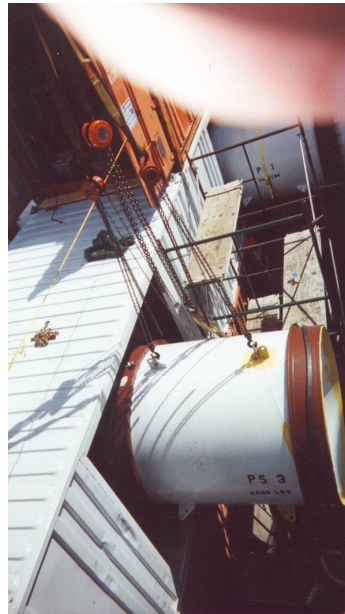
SRSS FABRICATION DETAILS



SRSS SHIP INSTALLATION DETAILS



SRSS SHIP INSTALLATION DETAILS



Remote Control Stimulator

Display



Remote Control Unit:

- Connected to main unit via cable
- Cable length can be varied

Amplitude:

- Selectable from low to high power level
- Toggle switch allows selectable display

E-Stop: Emergency shutdown

System Operation:

- Select ship's period based on loading
- Toggle Amplitude Switch to display:
- Select amplitude based on desired roll
Degrees of roll or feet of water
- Toggle period switch to display:

System Control:

Parameter	Min	Max
<u>Incr.</u>		
Power level	0	8
.05		
Period (sec)	6	26

Observed SRSS Performance

System performance and demonstration tests

**successfully performed during
November/December
at the Cheatham Annex, VA pier:**

- **Observed roll: ± 4 deg at maximum amplitude (8)**
ship's period of 12.5 sec

- Mooring lines slackened
- Exceeds design value of + 3 deg
- At anchor test (less restraint) can produce

Crane ATD Technologies Dual Use in Commercial Sector

►Potential uses for pendulation control technology:

- Ship or platform mounted cranes of the offshore oil, construction and heavy fabrication industries;**
- Salvage vessels and barge cranes, boat launching cranes and davits and cranes for over the side operations (rescue and buoy tending).**

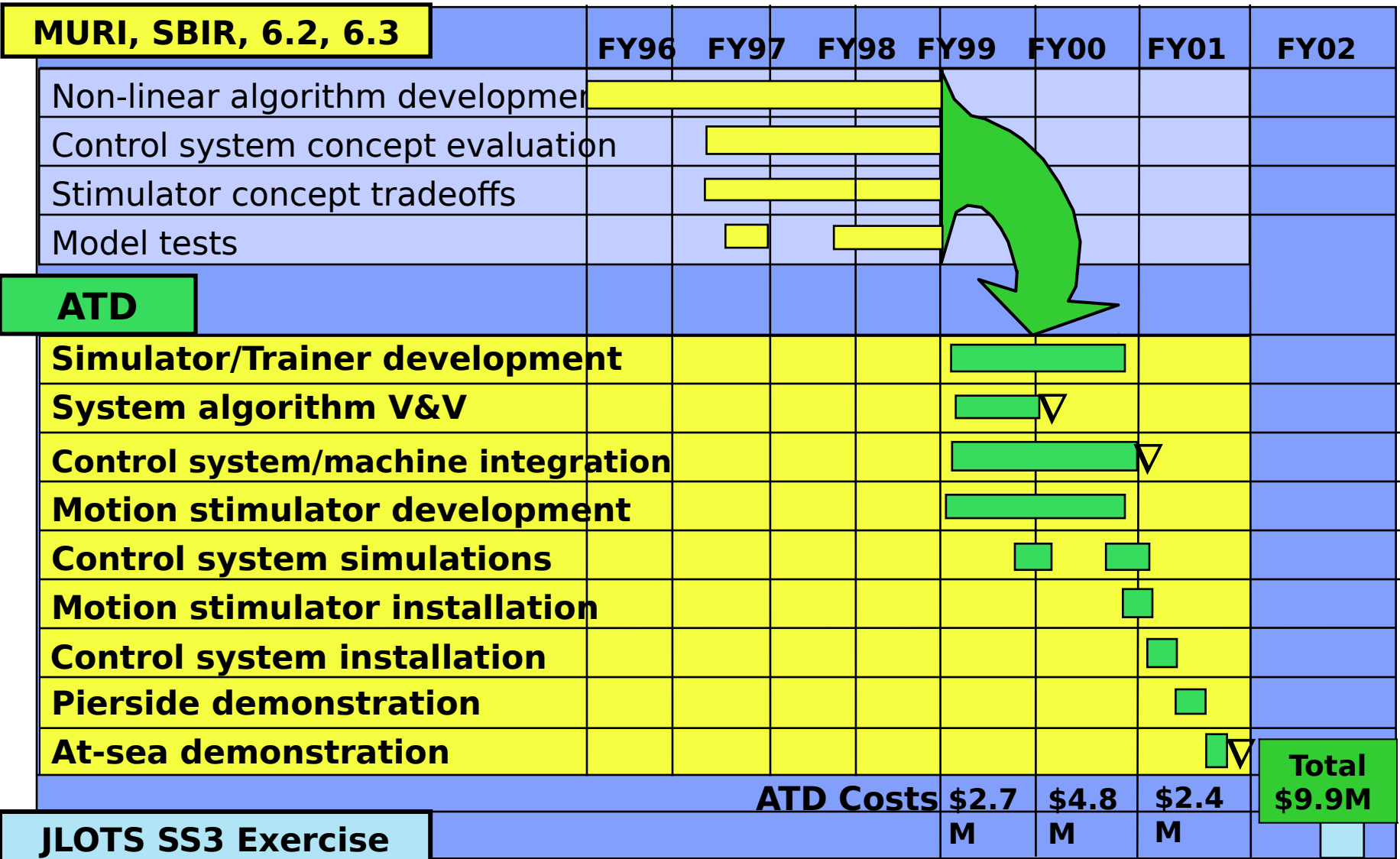
►Crane simulator exceeds normal commercial crane trainer requirements. May be of interest to crane technology developers.

►Roll Stimulator not believed useful in commercial applications; however, the inverse of this concept is believed useful to stabilize ships. Project to investigate funded by N42.

Issues

- ▶ **Ownership of the SRSS system - MARAD, NAVCHAPGRU or maintain as an N42 R&D testing asset. TBD following initial use as a training system for NAVCHAPGRU crane operators.**
- ▶ **Army Crane Operators would benefit if they used this as part of their training.**

Funding and Milestones



Transition

OPNAV N42_

National Defense Sealift Fund (PE 48042N)

PEO EXW, PMS325 Marty Fink

Strategic Sealift R&D Program

- **Final Design & Test (if required)**
- **Performance Spec / Acquisition Package**

Installation on:

- **Auxiliary Crane Ships 10 ships (54 cranes)**
- **Maritime Prepo Ships 16 ships (73 cranes)**

Potential installation on:

- **Fast Sealift Ships 8 ships (32 cranes)**
- **Large Medium Speed RO/RO 19 ships (76 cranes)**

Conclusion

Pendulation Control Algorithms

- Upgrade of Pendulation Control Algorithms **On Schedule**
- Crane Control System Upgrade **Completed**
- Crane Hydraulic System Upgrade Contract **On Schedule**

Crane Simulator/Trainer

- Crane Simulator System **On Schedule**

Roll Stimulator

- Roll Stimulator **Operational**

Funding Status - Spending total within original estimates